2012

Learning Outcomes From A Multidisciplinary, Hands-On, Think Tank.

Shannon Chance
Technological University Dublin, shannon.chance@tudublin.ie

John Marshall
The University Of Michigan

James Barber
College of William and Mary

Learning Outcomes from a Multidisciplinary, Hands-On, Think Tank

Dr. Shannon Chance, Dr. John Marshall, and Dr. James P. Barber

Hampton University, University of Michigan, and The College of William and Mary

SmartSurfaces provides University of Michigan students with an integrative, hands-on learning experience where cross-disciplinary teams design, build, program, and test interactive surfaces. The surfaces they produce have the capacity to adapt to information and environmental conditions.[1] Students in the course are majoring in architecture, art & design, and materials science & engineering. Some of them have had design courses before, but others have not. Through this course, student teams have designed heliotropic smartsurfaces (fall 2009), biomimetic smartsurfaces (fall 2010), and components for an off-the-grid house in Detroit (fall 2011). The course integrates concepts of environmental sustainability, and the theme has become more pronounced over the years.

The professors of this course – John Marshall, Max Shtein, and Karl Daubmann – describe *SmartSurfaces* as a multidisciplinary hands-on think tank.[2] Their course was developed as part of the university's Multidisciplinary Learning and Team Teaching Initiative (MLTT). In launching this initiative, the University of Michigan asserted that students "***must*** learn problem solving across disciplines and launch inquiries in uncharted territories of knowledge and practice. They ***must*** examine the assumptions that inhere in a disciplinary perspective and integrate material outside of patterns they are taught. They ***must*** locate issues within larger frameworks of thought, negotiate multiple perspectives, and develop habits of critical questioning and creative problem solving. In addition, they ***must*** learn how to find their way through disconnected bodies of information and perspectives and create their own path to a coherent education."[3] In 2009, the university launched *SmartSurfaces* and 14 other courses specifically designed to achieve these goals.

The university tracked some learning outcomes by surveying students who had completed MLTT courses. Crisca Bierwert, Kirsten Olds, and James Barber documented the results as part of their work for the university's Center for Research on Learning and Teaching (CRLT).[4] In the survey, *SmartSurfaces* students reported remarkably high levels of learning in the areas of critical thinking, oral communication, and creative thinking. The students' ratings of their learning far exceeded what students reported in other MLTT courses.

In the summer of 2011, John Marshall presented a detailed description of the course in a presentation at the Association of Collegiate Schools of Architecture (ACSA) annual Teachers' Seminar. The paper he and his colleagues published in proceedings of the Teachers' Seminar[4] provides valuable insight to educators hoping to develop innovative, multi-disciplinary, team-based design courses.

In all three iterations of *SmartSurfaces*, students were required to develop their own individual blogs to document, record, and reflect upon their experiences. Dr. Marshall, who holds a Ph.D. in Design and Technology, had taken extra steps during the initial planning stages of this course to secure consent from the university's Institutional Review Board (IRB), and from each student in the course, to collect and analyze data. Instructors frequently overlook the need to secure permissions upfront when they are designing new

courses. This is a crucial step in the knowledge generation and publication process.

From the outset of this course, Dr. Marshall had taken care to maintain research standards, track the students' blogs, and shoot video of each class session – thus compiling a rich trove of data for future analysis. This behavior is consistent with his own professional goal of developing "a discipline-agnostic, collaborative approach to designing and making that recognizes the boundaries of the problem being addressed, not the artificial boundaries of traditionally-defined disciplinary practice."[5]

The data archived by Dr. Marshall provided an ideal match for a study that Shannon Chance had proposed in the "implications for further study" portion of a presentation she made at the 2010 National Conference on the Beginning Design Student (NCBDS). The proceedings of that conference include her paper on the role of writing in architecture.[6] The paper discusses how to use writing to prompt reflection and facilitate metacognition / student development.

Dr. Chance, who teaches architecture at Hampton University and holds a Ph.D. in Higher Education, proposed to qualitatively analyze the data Dr. Marshall had collected. Because peer debriefing (i.e., critical, collaborative discussion of the researcher's interpretation of the data) is a crucial aspect of qualitative research, she solicited Dr. James Barber's involvement. Dr. Barber had been a member of the CRLT team at the University of Michigan who collected survey data from the MLTT students. Today, Dr. Barber teaches topics that include student development theory in the School of Education at The College of William and Mary in Virginia. All three researchers have been cleared by the University of Michigan IRB to work with the datasets and report their findings publically. Together, the three are working to identify patterns in the data related. They are using two different conceptual frameworks.

The first of these is the Integration of Learning (IOL) framework developed by Dr. Barber. Additional information about this framework is available in Dr. Barber's dissertation[7] (which earned the Dissertation of the Year Award from NASPA – Student Affairs Administrators in Higher Education) and in an article recently published in the *American Educational Research Journal* (AERJ).[8] As such, this first framework has been well documented and endorsed through the highest levels of peer review.

The second framework represents a new approach. It was developed by Dr. Chance as a result of her work on the 2010 NCBDS paper.[6] This new framework combines well-established student development theories with assessment strategies posed at the 2008 NCBDS by Dr. David Crismond, who teaches science education at the City College of New York.[9] In the second study, Dr. Chance is using *SmartSurfaces* data to (1) test the validity of a rubric she developed for assessing student development and (2) identify patterns in the data.

Both studies seek to understand how and what students have learned through their involvement in the *SmartSurfaces* course. The research team combines perspectives from the fields of architecture, art and design, education, and engineering. By discussing and interpreting patterns in collaboration, the team is able to draw from multiple fields and frameworks. This sort of triangulation helps each researcher extend the validity of his or her findings. Work to date has focused on analyzing blogs written by students in the fall of 2010 (the second time this course was offered).

The remainder of this paper will provide: (1) a brief description of the course, (2) instructions given to students in the *SmartSurfaces* course or writing blogs, (3) discussion of analysis underway using Dr. Barber's integration of learning framework, and (4) discussion of analysis underway using Dr. Chance's framework for assessing epistemological development.

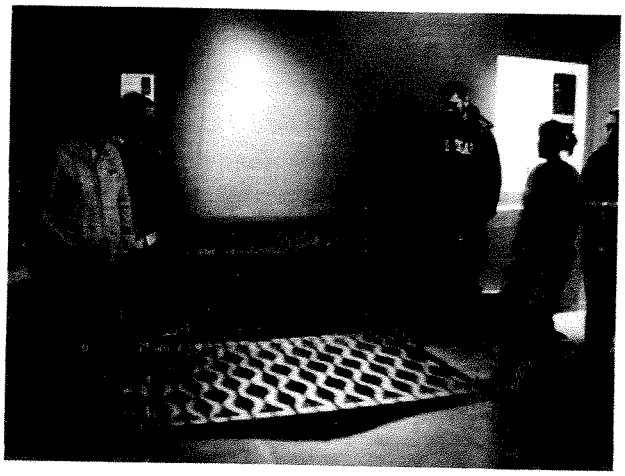

Fig. 1 & 2. Heliotropic surfaces from 2009. "Shy Solar Array" shown to the left and "Exposure" shown to the right.

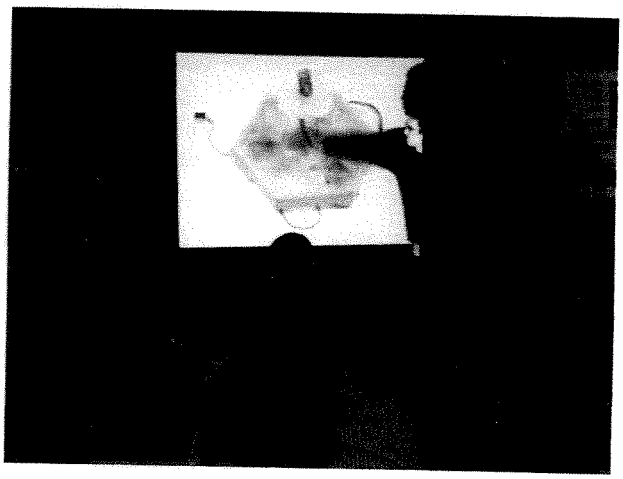

Fig. 3 & 4. Biomimetic surfaces from 2010. "Firefly Cloud" shown to the left and "Neural Window Reef" shown to the right.

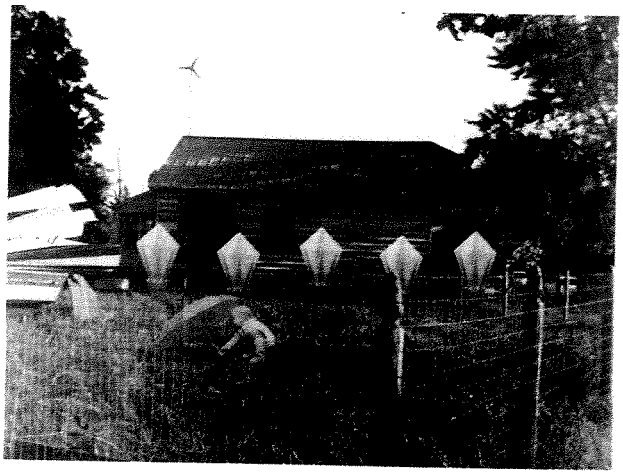

Fig. 5 & 6. Rendering of "Water Lilly" project from 2011 for Power House.

Brief Description of the Course

The *SmartSurfaces* course was designed and is jointly taught by professors from three different units (architecture, art & design, and materials science & engineering) at the University of Michigan. The course typically involves 24 students who are juniors or seniors. The students are distributed into four teams of six and each team receives $3000 to use to construct prototypes.

In 2009, each team was asked to design, build, program, and test a "heliotropic" smartsurface. The students had to come to terms with (purposefully) distributed authorship and challenging the (intentionally) under-defined parameters given to them (see Figures 1 and 2). The 2010 iteration focused on creating "biomimetic" smartsurfaces (see Figures 3 and 4).

The 2011 iteration of this course focused even more directly on environmental sustainability. Here, students designed, built, programmed, and tested smartsurfaces for an existing single-family home in Detroit that operates completely "off the grid." The "clients" were Gina Reichert and Mitch Cope who run Power House Productions, an incorporated nonprofit whose mission is to develop and implement neighborhood stabilization strategies in a Detroit neighborhood near Hamtramck. The Power House is used for artists' residencies in the local neighborhood.

The 2011 course investigated what *SmartSurfaces* for the Power House might be and how they might integrate with the needs of residents, neighbors, and the owners of the house. The students were asked to produce designs that could operate independently of all traditional public utility services. Initial work in the class investigated neighborhood-friendly interactive security devices, a re-imagining of what a window can be, a solar-powered hot water system, and a light well for growing citrus fruit indoors.

Blog Prompts

Each *SmartSurfaces* team member was required to maintain an individual, online blog describing the intent and progression of his or her work in the course. At a minimum, reference to each week's work and reflection of the person's role in the team was expected. Photos, video, drawings, and notes were recommended as valuable forms of documentation. The blogs were aggregated into a single feed and posted to the *SmartSurfaces* public website.

Learning objectives varied with respect to the students' disciplinary backgrounds. It was anticipated that the blogs should show the students' ability to identify relevant sources of information and to evaluate each source's importance in relation to each individual's studies. The blogs represent 20% of each person's semester grade. The other 80% was accounted for by assessment of the teamwork undertaken. Blog posts were expected to:

- Record, analyze, and organize observations, experiences, and insights
- Demonstrate the students' ability to reflect on their work and progress
- Document experiments with media, materials, techniques, and processes
- Explore precedents and examples of related projects

In 2011, Dr. Marshall prompted the students to blog by stating: "Every year people want to be told what to put in their course blogs. There is a PDF of sample posts in the 'Resources' section on [the *SmartSurfaces*] site. Very few ever follow through on actually reading the stuff available – so here is as best an answer as we can give:

Grab our attention by delivering outstandingly valuable, useful, or entertaining material – consistently. Instead of simply writing what you made this week, write about:

- How you made it - with pictures and/or video.
- What inspired it - if you like something, chances are we will like it too.
- Give concrete examples.
- Good blog posts include hyperlinks that provide pathways for readers to get more information.
- Invite comments by ending with a question (we will actually read your posts).
- Just get to the point, don't try to write an essay or poetry.
- Write from your own experience.
- Do not be afraid of sharing who you are, what inspires and moves you, and what defines you as a person in your blog posts.
- Don't sweat it - the most important thing is to keep doing it.
- Use a Creative Commons license to make it clear what people are allowed to do with your original work."

Integration of Learning

Our first research project involves examining the student blogs for integration of learning. Analysis is based on Dr. Barber's conceptual model.[7] In this model, integration is categorized using three increasingly complex categories:

1) Connection – in which a student recognizes a similarity between two ideas but does not take the link further
2) Application – in which a student uses knowledge or skills learned in one context in another context
3) Synthesis – a creative process in which the student brings together knowledge or skills from two or more contexts to form a new idea.

A team of trained research assistants worked together to code five student blogs from a single 2010 team. (A sixth member of the team had disabled his blog so it was no longer available publicly.) Each blog was reviewed by at least two researchers, and the team met weekly to discuss findings and align coding approaches.

To illustrate the *SmartSurfaces* students' integration of learning, three examples from Paul's blog[9] are featured in this paper. Paul is a junior Art & Design student. An early blog entry provides an example of making a "connection." Paul's introductory biography explains that he saw a flyer for this class in the Art & Architecture Building and immediately decided he needed to take it, because it seemed an excellent *juxtaposition of his interests in engineering and art* as well as a fascinating experiment in teamwork and the mixing of learning styles. He was excited that the theme for the year was *biomimicry, because that was the focus of his research and projects in a class he had taken the prior semester.* He found this to be a happy coincidence. (Italics are used to emphasize specific aspects of IOL.)

Paul's blog also reflected "application" consistent with the IOL definition. He noted that two other members of his team "both *brought origami books and experience to the table (literally and figuratively)*, which presented an interesting new concept for us: pyramids, triangles, and hexagons. *We went to work building a module out of six adjacent equilateral triangles* (each of which were in turn composed of four equilateral triangles...) which would fold into six triangular pyramids." This example occurred early in the semester. A passage Paul wrote following midterm illustrates "synthesis" according to the IOL model. Paul explains that one of the two students referenced above had just shown the team "a small model she had made of four chipboard squares on top of springs with a small blue fan under them. [See Fig. 4] *This went off of the suggestion we received in class to possibly use computer fans* and have air blowing at people and playing with a variety of both visual and sensory or perhaps 'felt' interaction. Unfortunately the fan had very little effect at moving the pieces

and they just sort of slightly wiggled around. *This did get us talking about creating some sort of walled area that could trap maybe hot air and release it at people as they walked by and played around with our "window wall."*

Preliminary analyses of the five students' blogs identified 87 examples of integration of learning. The examples were distributed similarly across the connection (n = 36) and application (n = 40) categories, with fewer examples categorized as synthesis (n = 16). Five of the examples fit into two categories, thus resulting in a number greater than 87 across all categories.

It is not surprising to find the majority (87%) of the examples categorized as connection and application, because the blogging assignment charges students to document the planning process toward the end point. Where synthesis does occur, it is weighted toward the last half of the semester. Comparing the general timeline of the blogs with the course syllabus and project schedule will illuminate how much the structure of the course itself (including the various tasks) influenced the students' integration of learning. It might be that deadlines for presentations or working prototypes align with the instances of synthesis in the students' writing.

The collaborative aspect of this project and the resulting dataset provide rich opportunities for exploration of integration of learning. Most of the students were reflective in their writing, and the blog format allowed students to include artifacts such as photographs, sketches, e-mails, and the like – to illustrate their stories. The team's blogs documented five students' perspectives on the same experiences. Individuals often described the experiences differently. As such, the description of a single event might be categorized as "connection" for one student (based on his / her description), but as "application" for another student (based on that individual's interpretation of the event).

In this initial approach to analyzing data for integration of learning, each individual's description of a particular experience was coded as a separate example. Taking a different approach might lead to examining a single event, and studying individuals' interpretations of the same learning experience. This might uncover important differences by characteristics such as gender, race / ethnicity, or academic program. Unpacking these nuances of individual learning versus collaborative or group learning will be key contributions of this project as it unfolds.

The data analyzed for the preliminary IOL findings is a small part of the larger data set available in the *SmartSurfaces* project. To date there have been three iterations of the course (2009, 2010, and 2011) with four teams of six students per course, for a total of 76 potential blogs. The analysis of these five students from a single team in 2010 has only scratched the surface.

Epistemological Development

At this point, the second project has involved preliminary assessment of 14 students' blogs with regard to design thinking and epistemological understanding. Dr. Chance analyzed blogs using a rubric that incorporates epistemological development models by Perry,[11] Baxter Magolda,[12] Belenky et al.,[13] and Love and Guthrie.[14] Each of these theorists contributed to society's understanding of how college students change over time. Specific terms vary from one theorist to the next, but all of their models assume students developed more sophisticated ways of thinking over time and that patterns can be generalized. According to Love and Guthrie, these models all have definitions that reflect low, middle, and high level achievement. The lowest is "unequivocal knowing" where the student sees things in black and white. The next is "subjectivist knowing" where the individual recognizes that multiple perspectives exist, but has little basis for determining which perspective to adopt when. The goal of educators is to help students reach the highest level, "generative knowing," where they can

make sound decisions appropriate to any given context. The rubric being used for this project's analysis overlays four developmental theories with the structure and content of Crismond's *Design Strategies Rubric*. The resulting rubric is too lengthy to include in this publication, but excerpts are included below.

A student operating at the lowest level (unequivocal knowing) conducts little exploration when starting a new design project. Such a student typically:

- Makes brief reading, overlooks research, and makes decisions prematurely[10]
- Looks for answers in external authorities[12]
- Reflects awe in authority figures (received), or reflects belief that own knowledge is superior to others (subjective)[12]
- Sees truth and knowledge as external to knower, not open to questioning, universal and context-free, constant, and the same everywhere [14]

A student at the middle level (subjectivist knowing) typically seeks to map a process for achieving results. Such a student often:

- Conducts some research[10]
- Sees instructor as providing context for exploration of knowledge[11]
- Emphasizes procedure with either evidence of doubt (separate knowing) or evidence of belief, empathy, and care (connected knowing)[12]
- Faces increased uncertainty, ambiguity, and complexity[13]
- Adopts view that all views are equally valid and that opinions are sources of truth[13]

At the highest level (generative knowing), the student plunges into exploration and embraces process as a means for generating new ideas. Here the student:

- Holds off on making decisions until challenge has been explored from many angles [10]
- Integrates existing information and research[10]
- Conducts quick studies / tests to explore a range of ideas[10]
- Includes personal experience and reflection (and may personally generate paradigms, insights, and judgments)[11]
- Reflects personal integration of info based on rational inquiry – from setting goals, to asking what is needed, how things work and why[11]
- Shows evidence of listening to others without losing his/her ability to 'hear' own voice[13]
- Realizes power to generate, produce, author, or originate own truths or realities[14]

Most scholars believe students do not typically reach the highest level during their undergraduate years. However, our preliminary analysis revealed a remarkable level of epistemological development within the *SmartSurfaces* group. Nine of the 14 students' blogs showed strong, consistent evidence of generative knowing. This level of development is remarkable, but also plausible considering design students are trained to make decisions in context. Moreover, the juniors and seniors who elect to take this extremely demanding 3-credit elective clearly welcome new challenges.

All of the blogs written by architecture students (n=5) reflected solid mastery of "generative knowing." This course did not replace the required design studio (which these students took at the same time as *SmartSurfaces*). This would likely deter all but the most dedicated students. The students' blogs indicate that *SmartSurfaces* provided them with valuable new collaborative structures, programming tools, multi-disciplinary topics, and team-teaching.

One engineering student began the semester reflecting mid-level development. His tone was detached and his comments focused on proce-

dure: "The progression was not without its dilemmas. Our group becomes puzzled by function. Many an hour was lost to debate of the purpose of things." His tone and level of engagement took a dramatic shift part way into the semester, however, when he realized his own power to generate new realities.[14] He explained, "I decided to learn rhino [software], taking any chance I could learn from the architects and art and design majors. To each I am very grateful. And I learned how to put together simple shapes as best I could. *But I was learning how to create and it felt exhilarating. Much more alive and enticing* than anything the college of engineering has thrown my way." He went on to say, "As engineers we learn theory. And theory is a clear divorce from practice. It is silly we even entertain the title of engineer. We are not good with our hands, nor are we good at innovation. We learn how to solve problems that have already been solved. Innovation only spews forth from empirically manipulating tangible things until they best serve a desired function."

Another engineering student described the thrill of generating new knowledge, as well. Her comments consistently reflected generative knowing: "*This was the first time I had ever made something that seemed to be an entity all by itself* once it was plugged into an electrical source. [See Fig. 4.] *It was really exciting and kind of changed the way I feel about design and creation.* Instead of trying to make a very specific thing with the exact attributes that you want you can make something and then let it tell you what you have made... [a professor] basically said the same thing during some of the presentations and *I wouldn't have really believed it until this project was done.* This also hits on my weaknesses thus far in Smart Surfaces," she said as she began to assess her own thought process.

The level of metacognitive thinking increased during the semester for many students. Writing, it appears, encourages such thinking and plays a role in promoting student development.

Implications for Further Study

As we move forward with our analyses, it will be interesting to see how Dr. Barber's IOL coding, Dr. Chance's cognitive development coding, and Dr. Marshall's quantitative evaluations inform each other. It will also be interesting to compare our findings with the syllabus... e.g., does organization of the course align with the learning evident in the blogs?

Notes

[1] http://www.smartsurfaces.net/Home

[2] Marshall, J., Shtein, M., & Daubmann, K. (2011). SmartSurfaces: A multidisciplinary, hands-on, think-tank. Presented at the ACSA Teachers Seminar.

[3] http://www.umich.edu/pres/init/team_final_report.pdf

[4] Bierwert, C., Olds, K., & Barber, J. P. (2010). *Student assessment of learning in Multidisciplinary Learning and Team Teaching (MLTT) courses. Report of a survey of students in fourteen MLTT-funded courses to the MLTT Steering Committee, Ben van der Pluijm, Chair.* Ann Arbor, MI: University of Michigan Center for Research on Learning and Teaching.

[5] http://art-design.umich.edu/people/detail/john_marshall

[6] Chance, S. (2010). Writing architecture: The role of process journals in architectural education. *MADE: Design education and the art of making* (160-170). Charlotte, NC: College of Arts + Architecture. Presented at the 26th National Conference on the Beginning Design Student in Charlotte, NC.

[7] Barber, J. P. (2009). Integration of learning: Meaning making for undergraduates through connection, application, and synthesis. (Doctoral dissertation). University of Michigan, Ann Arbor, MI.

[8] Barber, J. P. (2012). Integration of learning: A grounded theory analysis of college students' learning. *American Educational Research Journal.* http://aer.sagepub.com/content/early/2012/02/22/0002831212437854.full.pdf+html?ijkey=KUVaKvOZJkITE&keytype=ref&siteid=spaer

[9] Pseudonyms have been used in place of actual names, to honor the agreement made in the consent forms.

[10] Crismond, D. (2008, March 15). *Design Strategies Rubric*. The 24th National Conference on the Beginning Design Student. (Handout.) Atlanta, GA. Published in Chance, S. (2010). Strategic by design: Iterative approaches to educational planning. *Planning for Higher Education, 38*(2), 40-54. http://www1.scup.org/PHE/FMPro?-db=PubData.fp5&-lay=ART&-format=read_inner.htm&-error=error.htm&ID=PUB-DV20NwdoaLnfH0EnpL&-Find

[11] Perry, W. (1999), *Forms of ethical and intellectual development in the college years: A scheme*, 3rd ed., John Wiley and Sons , San Francisco.

[12] Baxter Magolda, M. B. (1995), The integration of relational and impersonal knowing in young adults' epistemological development, *Journal of College Student Development*, Vol. 36, No. 3.

[13] Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986), *Women's ways of knowing: The development of self, voice, and mind*, Basic Books, New York.

[14] Love, P. G., and Guthrie, V. L. (Winter 1999), Synthesis, assessment, and application, New direction for student services, Vol. 1999, No. 88, pp. 77-93.